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NEEDLE BIOMASS EQUATIONS FOR SINGLELEAF PINYON ON THE VIRGINIA RANGE, NEVADA

T. R. De Rocher[1] and R. J. Tausch[2]

ABSTRACT.—Foliar biomass of singleleaf pinyon (*Pinus monophylla* Torr. & Frem.) was estimated on the Virginia Mountains, Nevada, based on the easily measured dimensions of crown volume and sapwood area. Leaf biomass estimation techniques used in other studies of pinyon where total leaf biomass was collected were supported. Both sapwood area (cm^2) and crown volume, calculated as one-half of an ellipsoid (m^3), were found to be significantly related to total dry weight needle mass (g). Best predictive equations for crown volume were obtained with nonlinear regression analysis. A previously reported two-part relationship based on tree size for predicting needle biomass with sapwood area was supported. Foliar biomass of singleleaf pinyon can be accurately estimated with a minimum of 10 sapwood cores.

Key words: singleleaf pinyon, foliage biomass, sapwood area, biomass prediction.

In recent years land managers trying to fulfill the goal of multiple use have needed to ascertain the potential value and use of pinyon-juniper woodlands extending over 17 million ha across the Rocky Mountain and Great Basin regions (Chojnacky 1986). Singleleaf pinyon and Utah juniper (*Juniperus osteosperma* Little) woodlands cover more than 6 million ha in the Great Basin alone (Tausch and Tueller 1990). This forest type has historically supplied fuelwood, charcoal, nuts, fence posts, and poles (Fogg 1966), especially during heightened mining activity in the late 1800s (Budy and Young 1979). Pinyon-juniper forests also provide essential areas for wildlife habitat (McCulloch 1969, Short and McCulloch 1977, Balda and Masters 1980). Balancing out these benefits is the nearly complete loss of forage and potential increased soil erosion resulting from the establishment of this species (Doughty 1987).

Estimates of biomass are essential to most studies of plant community competition, succession, and resource allocation including studies of pinyon-juniper woodlands. Total foliar biomass, or phytomass, can be vital to assessment of plant water-use efficiency (Long et al. 1981, Waring 1983), nutrient cycling (Waring and Running 1978), soil moisture conditions (Grier and Running 1977), the hydrologic environment (Nemani and Running 1989), and competitive interactions (Tausch and Tueller 1990). The amount of foliage biomass on a tree is strongly related to the area of conducting tissue transporting water and nutrients to these tissues. This relationship has been found for many conifers (Grier and Waring 1974, Kaufmann and Troendle 1981, Marchand 1984, Miller et al. 1987), including pinyon (Tausch and Tueller 1989). Survival of trees in arid environments demands efficiency, and production of excess xylem and associated supporting tissue would waste precious resources. Alternately, insufficient development of conducting tissue would dehydrate and starve a tree. Also, as a tree grows, its mass and the spatial volume it inhabits expand in a nonlinear fashion (Tausch and Tueller 1988).

Many studies have shown close relationships between whole-tree phytomass and easily measured plant dimensions (Budy et al. 1979, Miller et al. 1981, Cochran 1982, Hatchell et al. 1985, Tausch and Tueller 1989, 1990). Measuring needle mass of entire singleleaf pinyon (*Pinus monophylla* Torr. & Frem.) trees through harvest can be inefficient and expensive (Meeuwig and Budy 1979), especially on large trees in remote areas. The ability to accurately estimate phytomass based on simple allometric measurements can greatly ease the process. Cross-sectional sapwood areas for pinyon pine can be estimated with a high degree of accuracy using increment cores and trunk diameter measurements (Whitehead 1978, Tausch 1980). Equations generated by these procedures can apparently vary for this

[1]Department of Range, Wildlife and Forestry, University of Nevada–Reno, Reno, Nevada 89512.
[2]U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Reno, Nevada 89512.

species depending on location in the Great Basin (Tausch and Tueller 1988). Development and refinement of techniques to acquire reliable mensurational data will only enhance the further study, understanding, and proper management of pinyon-juniper woodlands. The objective of this study was to apply evolved methods of estimating whole-tree needle biomass to singleleaf pinyon on a third Great Basin site.

METHODS

Study Area

Research was conducted on USDI Bureau of Land Management pinyon-juniper woodlands 32 km SE of Reno, Nevada (39°17'30"N, 119°42'30"W). The study site lies at 1963 m elevation in a near level east-west saddle formed between a basalt plug and the west-facing slope of the Virginia Mountains. Soils are 0–10 cm deep and poorly developed from decomposed Cretaceous granodiorite and Pliocene-Pleistocene volcanics. This area receives approximately 336 mm of precipitation annually (Desert Research Institute 1991), mostly as snow. Some Utah juniper occurs in the area, but singleleaf pinyon is the dominant tree species.

Field Techniques

Tree selection procedures were based on the five maturity classes described in Blackburn and Tueller (1970). Ten trees from each maturity class were randomly selected for potential measurement within relationships of accessibility associated with placing potometers for tree water-use studies (De Rocher 1992). Five trees from each maturity class were randomly selected for a total of 25 trees to be measured and harvested. Total tree height (cm), canopy height (cm), maximum canopy diameter and canopy diameter perpendicular to the maximum (cm), and trunk circumference (cm) at approximately 15 cm above the root crown were determined for all trees.

Past studies have shown that including estimates of canopy density improves predictability of needle biomass (Miller et al. 1981), but visual estimates used were not easily comparable between studies. Canopy needle biomass density decreases as voids develop within the canopy with increasing age. Error can be introduced in needle biomass estimation based on crown volume calculated from simple canopy dimensions without an estimate of the voided space. This study incorporated a grid method of determining average canopy density similar to the method proposed by Belanger and Anderson (1989). The procedure involved viewing each sampled tree canopy through a 6 × 60-cm Plexiglas sheet that had a 3-cm^2 grid transposed onto it. A perspective was chosen that approximated an average of canopy fullness that was sufficiently distant to visually contain the entire tree height within the vertically held grid when viewed at arm's length. First, the left upright edge of the grid was then aligned with the trunk and the canopy height centered within the grid. This placed the grid over the right side of the tree. Within the grid a smooth canopy border was imagined as if a ribbon were stretched from the top along the outside edge of the canopy to the base. Next, grid squares more than halfway within this perimeter line were counted for the maximum area covered by the canopy. Last, squares within the perimeter covered by >50% foliage (versus open space, trunk, or branches) were counted. Dividing the number of foliage-covered squares by the total number of squares within the canopy perimeter determined a ratio of relative canopy density. This procedure was then repeated by placing the grid over the left side of the tree canopy.

Following crown measurements and estimation of canopy density, all green foliage was harvested by cutting off branches and placing them in feed bags. After being air-dried, the needles were dried at 80°C for 24 h to achieve consistency and then weighed. A trunk cross section was also cut approximately 15 cm above the root crown. These cross sections were measured for sapwood area (cm^2) using a paper trace, which was cut into small pieces and run through a model LI-3100 leaf area meter (LI-COR, Inc., Lincoln, Nebraska).

Analysis Techniques

Longest crown diameter, diameter perpendicular to it, and crown height for each tree were used to compute the crown volume (m^3) based on the formula for one-half of an ellipsoid (Tausch 1980, Beyer 1984). Crown volume was also adjusted for canopy density by

TABLE 1. Singleleaf pinyon foliar mass prediction models using sapwood area and crown volume approximated as one-half of an ellipse.

Relation	Equation	R^2	Standard error of estimate
	Linear regression		
Needle vs. sapwood Mass (g) Area (cm^2) (All maturity classes)	$Y = 265.3 + 122.1X$	.977	4059
Needle vs. sapwood Mass (g) Area (cm^2) (Trees $<40 cm^2$ sapwood)	$Y = -142.5 + 106.4X$	.947	227
Needle vs. sapwood Mass (g) Area (cm^2) (Trees $>40 cm^2$ sapwood)	$Y = 3234.7 + 117.4X$	.971	6822
	Log transformed linear regression		
Needle vs. sapwood Mass (g) Area (cm^2) (All maturity classes)	$\ln Y = 35.31 + 1.24 \ln X$	.782	16,886
Needle vs. sapwood Mass (g) Area (cm^2) (Trees $<40 cm^2$ sapwood)	$\ln y = 33.9 + 1.37 \ln X$	.973	194
Needle vs. sapwood Mass (g) Area (cm^2) (Trees $>40 cm^2$ sapwood)	$\ln Y = 186.5 + 0.94 \ln X$	.970	6453
	Nonlinear regression		
Needle vs. sapwood Mass (g) Area (cm^2) (All maturity classes)	$Y = 181.4X^{0.94}$	.989	3847
Needle vs. sapwood Mass (g) Area (cm^2) (Trees $<40 cm^2$ sapwood)	$Y = 20.1X^{1.497}$	.995	83
Needle vs. sapwood Mass (g) Area (cm^2) (Trees $>40 cm^2$ sapwood)	$Y = 194.4X^{0.929}$	.970	6444
Needle vs. ellipsoid Mass (g) Volume (m^3) (All maturity classes)	$Y = 2.34X^{0.58}$	.976	5643
Needle vs. ellipsoid Mass (g) Volume (m^3) (Adjusted for canopy density) (All maturity classes)	$Y = 1.36X^{0.62}$	.977	5459

multiplying the calculated volume by the canopy density ratio. Two types of regression analyses were used to evaluate relationships between oven-dry foliage weight and sapwood area and crown volume. Prediction equations utilizing any form of data transformation to linearize the data for least-squares analysis were repeated using nonlinear regression with the original untransformed data (Tausch and Tueller 1988), and the best fit results are reported. Comparisons among regression results were made using highest coefficients of determination (R^2) and lowest standard error of the estimate values, to a level of significance of $p < .01$ for the least-squares analyses results.

RESULTS AND DISCUSSION

The amount of foliage supported per unit area of conducting tissue ranged from 37.4 g cm^{-2} for the smallest tree to 157.2 g cm^{-2} for one of the largest, and averaged 88.8 g cm^{-2} for all sampled trees. Using a nonlinear regression technique that iteratively approximates optimal fit without data transformation provided as tight a fit to the full data set as linear regression utilizing log-transformed data in relating dried needle mass and sapwood area. Reapplication of untransformed data to linear models decreased the relationship (Table 1). For trees with <40 cm^2 sapwood area (maturity classes 1–3), this relationship was definitely nonlinear, as was observed by Tausch and Tueller (1989). The slope of the linear regression line for these western Nevada data is nearly identical to the slope for pinyon from southwestern Utah (Tausch 1980), suggesting a potential singular relationship across the Great Basin. For both these data and the Tausch 1980 southwestern Utah data, the entire foliage was harvested from each tree. A similar relationship was not found between data from Tausch 1980 and Tausch and Tueller 1989. Tausch and Tueller (1989) utilized a foliage subsampling technique to estimate total needle biomass, which may have underestimated the needle biomass to sapwood area ratio.

Correlation between needle biomass and the calculated elliptical crown volume was also significant by nonlinear regression (Table 1). When adjusted for percent canopy density, the linear elliptical volume relationship was improved (R^2 = .98), and the standard error of the estimate simultaneously was reduced from 5643.1 to 5458.9.

CONCLUSIONS

Prediction of foliar mass using sapwood area of singleleaf pinyon on the Virginia Mountains, Nevada, was equivalent in precision to previously reported results for this species conducted in southwestern Utah (Tausch 1980). Elliptical crown volume calculated from canopy widths and crown height again proved to be a significant predictor of dry weight phytomass. Adding an estimate for variations in canopy density further improved the relationships. As previously reported (Tausch and Tueller 1989), application of nonlinear regression analysis produced the best fit between phytomass and all tree dimensions, as reflected by increased coefficient of determination values and reduced standard errors of the estimate over other regression methods.

Estimates of singleleaf pinyon phytomass for hydrological and ecological studies of pinyon-juniper woodlands can be most accurately obtained from a minimum of 10 sapwood area measurements. Canopy dimensions and an assessment of foliage density can also be used to reliably estimate whole-tree phytomass. This study, conducted on the western edge of the Great Basin, achieved needle biomass regressions based on sapwood area that were nearly identical to those from work performed in southwestern Utah. Future research should concentrate on comparing numerous isolated studies across the Great Basin of whole-tree foliar mass harvest so that a regional biomass equation may be developed.

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